Plant Diversity of the Damietta Branch, River Nile, Egypt: An Ecological Insight

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Abstract

Damietta Branch; one of the two main branches of the River Nile has a length of about 242 km with an average width of 200 m and depth varying between 12 and 20 m. It receives polluted waters from different sources including industrial, agricultural and urban sewage that are causing serious environmental impacts on its vegetation and freshwater. The total number of plant species in the study area is 70, belonging to 54 genera and related to 30 families. These species can be classified ecologically into four major groups, three submerged hydrophytes, six floating hydrophytes, seventeen emergent species and 44 canal bank species. On the basis of duration, the recorded 70 species are grouped into two categories: perennials (46 species) and annuals (24   species). Hydrosoil and water variables which significantly correlated with the abundance and distribution of vegetation groups are soil texture (sand and silt), water-holding capacity, electrical conductivity, soluble anions (chloride and sulphate), total phosphorus and extractable cations (sodium, calcium and magnesium). The successive changes of the macrophytic plant vegetation in the Damietta Branch are frequently results from human activities which are causing considerable change in the hydrosoil and water chemistry, factors linked with species changes.

Keywords; Damietta Branch, hydrophytes, sediments, water chemistry.

Introduction

The River Nile is the major regular and voluminous supply of water secured in Egypt [1, 2]. Building of dam across a river and impounding water behind it may cause profound changes in the limnological regime of the water body (1988). These may include chemical and physical changes which in turn are affecting the biota of the rivers. This can be observed in Egypt after the establishment of Aswan High Dam (1965) where the River Nile is under complete control northwards the body of the dam.

Ali et al. [3] found that the water level regime in Lake Nasser is strongly dependent on the flood pattern in the River Nile, a high amplitude of water level fluctuations was recorded in 1988 (after the drought period). On the other hand, a continuous low water level exposed the littoral shallow water

habitat and submerged macrophytes became exposed and desiccated. Following this a period of continues high water level causes low light condition for the same area of the littoral zone.

Damietta Branch; one of the two main branches of the River Nile; passes through five governorates with a length of about 242 km with an average width of 200 m and depth varying between 12 and 20 m [4]. It has a great vital importance, since it serves as the major source of water for municipal, industrial, agricultural, navigation and feeding fish farms dispersed between El-Serw to Faraskour region [5].

The distribution and abundance of aquatic plants are influenced by many factors. Nutrients are the most important factor for the submerged plant growth and distribution, although, nutrient enrichment in water could inhibit the growth of some aquatic plants. Johnson and Ostrofsky demonstrated the importance of sediment characteristics in determining macrophyte community structure. Van Donk and Otte [6] reported that fish grazing on macrophytes affects the internal balance among autotrophic components by changing composition and lowering the macrophyte standing crop. Middelboe and Markager [7] and Armengol et al. [8] reported that water depth is the most important factor influencing water transparency and hence distribution of the submerged plants varies with depth. Water velocity not only affects the abundance of submerged plants [9], but also controls gas exchange processes [10]. The present paper accounts briefly on the floristic status and ecological characteristics of the macrophytic plant vegetation in the Damietta Branch, River Nile in Egypt.

Materials and methods

Study Area

The study area is mainly located in the main stream of the Damietta Branch of the River Nile passing through five governorates of the Nile Delta namely: Damietta, El-Dakahlyia, El-Gharbia, El-Menofyia and El-Qaluobya (Figure 1).

The climate of Egypt is generally arid [1]. However, extreme arid climate prevails in Upper Egypt high temperature, low relative humidity (29-53%), high evaporation rate (8.6-20 mm/day) and negligible rainfall (1.4mm- 5.3 mm/year). Climatic aridity gradually decreases northwards. At the Delta barrage area the annual rainfall is 20.8 mm increasing northwards to 160 m along the Deltaic Mediterranean coast 160 mm in Rosetta and 102.3 mm at Damietta.

Estimation of species abundance

Sixty stands were selected northwards to describe the plant life in the four ecological sites along the Damietta Branch. In each stand all plant species were recorded in five plots (25 m^2 each) and the species abundance was estimated in one sampled stand according toMuller-Dombios and Ellenberg [11]. The importance values of the recorded species were expressed by the relative values of frequency calculated for each species. The identification and nomenclature of the recorded species were according to Tackholm [12] and Boulos [13].

Sediment analysis

Sediment (hydrosoil) samples were collected from stands of the ecological sites for soil analysis. The texture of hydrosoil samples was determined by Bouyoucos hydrometer method, special rectangular
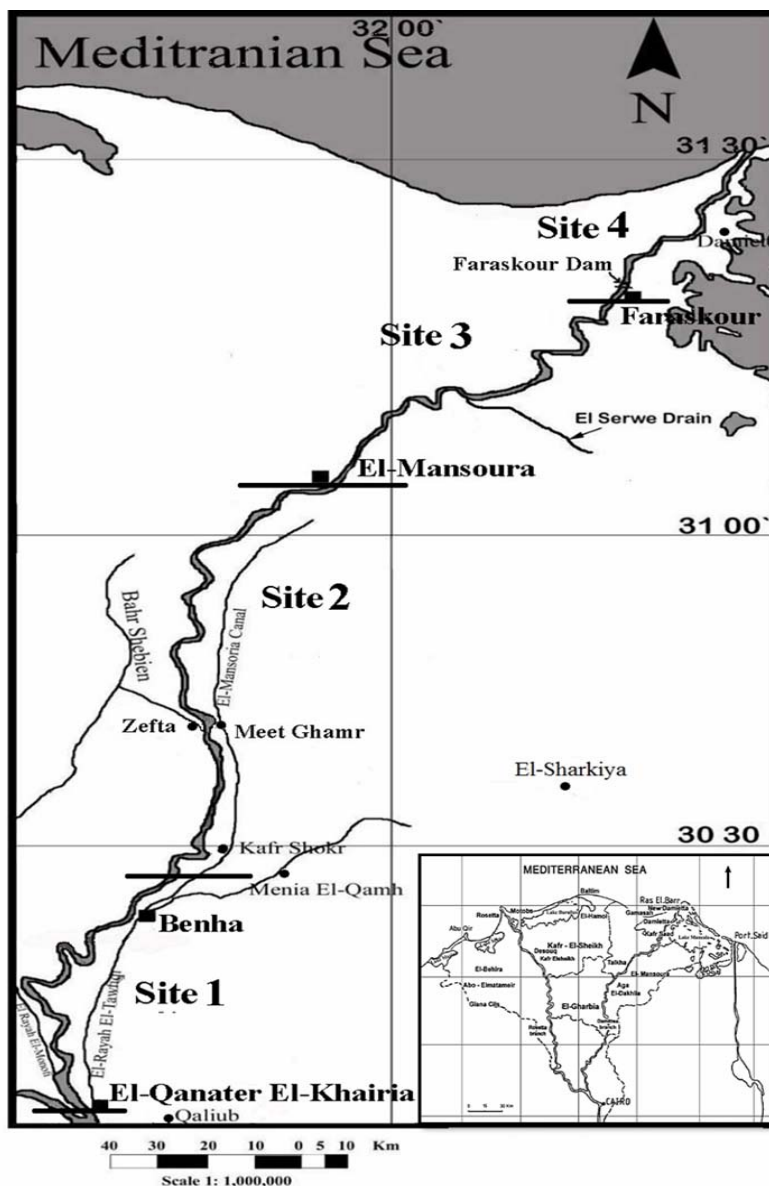
Ecological sites

    1= El-Qanater El-Khayria – Benha   **2**= Benha – El-Mansoura
    3= El-Mansoura - Farskour**4** = Farskour – Ras El-Bar

Figure (1). Map of the Damietta Branch showing the four ecological sites
       of the study area.

box (Hilgard pan box) was used for the determination of water-holding capacity. Oxidizable organic carbon was determined using Walkely and Black rapid titration method [14] Calcium carbonate content was determined according to Jackson [15]. Electeric pH-meter (Model Lutron YK-2001pH meter) digital analyzer with glass electrode was used to determine the soil reaction in 1: 5 soil extract. Electrical conductivity was measured by YSI Incorporated Model 33 conductivity meter. Carbonates and bicarbonates were determined by titration method using 0.1N hydrochloric acid [16]. Estimation of chlorides was carried out by titration method using N/35.5 silver nitrate and potassium chromate indicator [14]. Suphates were estimated gravimetrically using 5% barium chloride solution which

precipitated as barium sulphate and ignited in muffle furnace at 700-800 °C. The total dissolved phosphorus was determined by direct stannous chloride method [17], while the total nitrogen was determined by the micro-Kjeldahl method according to Allen et al. [18].

Water analysis

In situ the water samples were collected and kept in polyethylene bottles from which 1000 cm3 aliquots, transferred to laboratory, filtered through CF/C glass fiber filters. The filtrates were stored at 4 °C in dark bottle to be used for chemical analysis. Another raw sample was acidified to pH 2.0 using nitric acid to preserve the metals in samples. Water temperature was measured using, YSI model 33 S.C.T. meter, electrical conductivity was measured directly using conductivity meter (Model Corning, NY 14831 USA), The pH value of surface water was measured in situ by using Electrical-pH meter (Model Lutron YK-2001pH meter). Dissolved oxygen and oxygen saturation were measured directly using dissolved oxygen meter (Lutron YK-22 DO meter). Determination of the BOD was carried out using the conventional Winkler method. Determination of COD was carried out using the dichromate reflux method [17]. Calcium carbonate content was determined according to Welch [19].

Chloride content was determined by Mohar's method as described in American Public Health Association [17]. Sulphate content was estimated gravimetrically using 5% barium chloride solution according to Jackson [15].Water-soluble carbonates and bicarbonates were determined according to Baruah and Barthakur[20]. Total phosphorus was measured in unfiltered water samples according to APHA [17]. The total nitrogen was determined by the micro-Kjeldahl method according to Allen et al. [18]. The method of extraction of different elements was described by Allen et al. [21]. Sodium and potassium were determined in all samples by Flame Photometer (Model PHF 80 B Biologie Spectrophotometer), while Ca and Mg were estimated by using Atomic Absorption Spectrometer (A Perkin-Elemer, Model 2380, U.S.A.).

Multivariate analysis of the data

Two way indicator species analysis (TWINSPAN) and Principal Component Analysis (PCA) were applied for the classification of stands into groups and ordinate stands in two-dimensional space based on the importance values of species. The relation between the vegetation and soil gradients was assessed using Canonical Correspondence Analysis (CCA) [22,23,24). Data of the soil variables of the vegetation groups identified by TWINSPAN were compared by one-way ANOVA. Linear correlations coefficient (r) was calculated for assessing the relationship between the estimated soil variables on one hand and the community variables, on the other hand. The one-way ANOVA and correlation analyses were conducted using SPSS 16 for Windows.

Results

Floristic analysis

The flowering plant species in the study area were 70, belonging to 54 genera and 30 families (Table 1). They are classified into four groups. The first group included *Ceratophyllumdemersum* and *Myriophyllumspicatum* recorded in three sites of the Damietta Branch, (P =75 %) and *Potamogetonperfoliatus* observed in only one site of the study area (P =25%).

The second group included *Eichhorniacrassipes* and *Ludwigia stolonifera* represented 75%. *Lemnagibba* has been recorded in 2 sites (P= 50%). The other three species namely *Pistia stratiotes*,

Table 1. Floristic composition of the different ecological sites in Damettia Branch of the River Nile, Egypt.

No.	Species	Life span	Life form	Chorotype	Ecological sites				NS	P %
					Site 1	Site 2	Site 3	Site 4		
A) Hydrophytes										
1- Submerged hydrophytes										
1	*Ceratophyllumdemersum* L.	Per.	Hy	COSM	+	+	+	-	3	75
2	*Myriophyllumspicatum* L.	Per.	Hy	ME+ER-SR+IR-TR	+	+	+	-	3	75
3	*Potamogetonperfoliatus*L.	Per.	Hy	ME+ IR-TR	+	-	-	-	1	25
2-Floating hydrophytes										
1	*Eichhorniacrassipes* (C. Mart.) Solms	Per.	Hy	NEO	+	+	+	-	3	75
2	*Ludwigia stolonifera*Guill. &Perr.	Per.	He	S - Z	+	+	+	-	3	75
3	*Lemnagibba* L.	Per.	Hy	COSM	-	+	+	-	2	50
4	*Lemna minor* L.	Per.	Hy	COSM	-	+	-	-	1	25
5	*Pistia stratiotes* L.	Per.	Hy	PAN	-	-	+	-	1	25
6	*Potamogetonnodosus*Poir.	Per.	Hy	ME+IR-TR	-	+	-	-	1	25
3- Emergent species										
1	*Phragmitesaustralis* (Cav.) Trin. exSteud.	Per.	G, He	COSM	+	+	+	+	4	100
2	*Alternantherasessilis* (L.) DC.	Per.	He	PAN	+	+	+	-	3	75
3	*Cyperusalopecuroides*Rottb.	Per.	He	PAN	+	+	+	-	3	75
4	*Cyperus articulates* L.	Per.	G, He	PAL	+	+	+	-	3	75
5	*Cyperusdifformis* L.	Ann.	Th	PAL	+	+	+	-	3	75
6	*Cyperus papyrus* L.	Per.	G, He	PAL	-	-	+	-	1	25
7	*Echinochloastagnina* (Retz.) P. Beauv.	Per.	G, He	PAL	+	+	+	-	3	75
8	*Persicarialapathifolia* (L.) Gray	Per.	G	PAL	+	+	+	-	3	75
9	*Persicariasalicifolia* (Willd) Assenov	Per.	G	PAL	+	+	+	-	3	75
0	*Ranunculus sceleratus* L.	Ann.	Th	ME+IR-TR+ER-SR	+	+	+	-	3	75
11	*Saccharumspontaneum* L. Mant. Alt	Per.	G, He	ME+PAL	+	+	+	-	3	75
12	*Typhadomingensis*(Pers.) Poir. ex Steud	Per.	He	PAN	+	+	+	-	3	75
13	*Veronica anagallis - aquatica*L.	Per.	He	COSM	+	+	+	-	3	75
14	*Cyperuslaevigatus* L.	Per.	G, He	PAL	+	-	+	-	2	50
15	*Leersiahexandra* Sw.	Per.	He	PAN	-	+	+	-	2	50
16	*Panicumrepens* L.	Per.	G	PAN	-	+	-	-	1	25
17	*Persicarialanigera* (R. Br.) Sojak	Per.	G	PAL	-	-	+	-	1	25
B) Canal bank species										
1	*Alhagigraecorum*Boiss.	Per.	H	ME+SA-SI	+	+	+	+	4	100
2	*Cynanchumacutum* L.	Per.	H	ME+IR-TR	+	+	+	+	4	100
3	*Cynodondactylon* (L.) Pers.	Per.	G	COSM	+	+	+	+	4	100
4	*Plucheadioscoridis* (L.) DC.	Per.	Nph	S-Z+SA-SI	+	+	+	+	4	100
5	*Symphyotrichumsquamatum*(Spren.) Nesom	Per.	Ch	NEO	+	+	+	+	4	100
6	*Amaranthusgraecizans*L.	Ann.	Th	ME+IR-TR	+	+	+	-	3	75
7	*Amaranthusviridis* L.	Ann.	Th	ME+IR-TR	+	+	+	-	3	75
8	*Arundodonax* L.	Per.	He, G	Cult.& Nat.	+	+	+	-	3	75
9	*Bassiaindica* (Wight) A. J. Scott	Ann.	Th	S-Z+IR-TR	+	-	+	+	3	75
10	*Bidenspilosa* L.	Ann.	Th	PAN	+	+	+	-	3	75

11	*Chenopodium album* L.	Ann.	Th	COSM	+	+	+	-	3	75
12	*Chenopodiummurale* L.	Ann.	Th	COSM	+	+	+	-	3	75
13	*Convolvulus arvensis* L.	Per.	H	COSM	+	+	+	-	3	75
14	*Conyzabonariensis*(Willd.) Tackh.	Ann.	Th	NEO	+	+	+	-	3	75
15	*Cyperusrotundus* L.	Per.	G	PAN	+	+	+	-	3	75
16	*Ecliptaprostrata*(L.) L.	Ann.	Th	NEO	+	+	+	-	3	75
17	*Imperatacylindrica*(L.) Raeusch.	Per.	H	PAL	+	+	+	-	3	75
18	*Ipomoea carnea*Jacq.	Per.	Ch	Cult. & Nat.	+	+	+	-	3	75
19	*Portulacaoleracea* L.	Ann.	Th	COSM	+	+	+	-	3	75
20	*Rumexdentatus* L.	Ann.	Th	ME+IR-TR+SA-SI	+	+	+	-	3	75
21	*Tamarixnilotica*(Ehrenb.) Bunge	Per.	Nph	SA-SI+S-Z	+	+	-	+	3	75
22	*Solanumnigrum* L.	Ann.	Th	COSM	+	+	+	-	3	75
23	*Sonchusoleraceus* L.	Ann.	Th	COSM	+	+	+	-	3	75
24	*Amaranthuslividus* L.	Ann.	Th	ME+IR-TR	+	+	-	-	2	50
25	*Echinochloacrusgalli*(L.) P. Beauv.	Ann.	Th	PAN	-	+	+	-	2	50
26	*Ethuliaconyzoides* L.	Ann.	Th	PAL	+	+	-	-	2	50
27	*Malvaparviflora* L.	Ann.	Th	ME+IR-TR	+	+	-	-	2	50
28	*Phyla nodiflora* (L.) Greene	Per.	Ch	PAN	-	+	+	-	2	50
29	*Suaedapruinosa*Lange	Per.	Ch	ME	+	-	-	+	2	50
30	*Arthrocnemummacrostachyum* (Moric.) K. Koch	Per.	Ch	ME+SA-SI	-	-	-	+	1	25
31	*Atriplexprostrata* DC. in Lam.	Ann.	Th	ME+ER-SR+IR-TR	+	-	-	-	1	25
32	*Atriplexportulacoides* L.	Per.	Ch	ME+IR-TR+ER-SR	-	-	-	+	1	25
33	*Atriplexsemibaccata* R. Br.	Per.	H	AUST	-	-	-	+	1	25
34	*Chenopodiumficifolium* Sm.	Ann.	Th	ME+ER-SR	-	+	-	-	1	25
35	*Daturastramonium*L.	Ann.	Th	NEO	-	-	+	-	1	25
36	*Halocnemumstrobilceum* (Pallas) M. Bieb.	Per.	Ch	ME+IR-TR+SA-SI	-	-	-	+	1	25
7	*Heliotropiumcurassavicum*L.	Per.	Ch	NEO	-	-	-	+	1	25
38	*Mesembryanthemumnodiflorum* L.	Ann.	Th	ME+SA-SI+ER-SR	-	-	-	+	1	25
39	*Oxalis corniculata*L.	Per.	H	COSM	-	+	-	-	1	25
40	*Pennisetumsetaceum* (Forssk.) chiov.	Per.	H	ME+PAL	-	-	+	-	1	25
41	*Phoenix dactylifera*L.	Per.	MMPh	Cult.	-	-	-	+	1	25
42	*Ricinuscommunis*L.	Per.	Nph	Cult. & Nat.	-	+	-	-	1	25
43	*Senecioaegyptius*L.	Ann.	Th	ME+IR-TR+ER-SR	-	+	-	-	1	25

Abbreviations:
Ecological sites: 1= El-Qanater El-Khayria–Benha, **2**= Benha–El-Mansoura, **3**= El-Mansoura–Farskour, **4** = Farskour–Ras El-Bar; **NS** = Number of sites in which the plants is recorded; **P%** = Presence percentage; **life-span:** Per. = Perennials, Ann. = Annuals; **life-form:** Nph = Nanophanerophytes, Ch = Chamaephytes, H = Hemicryptophytes, G = Geophytes, He = Helophytes, Hy = Hydrophytes, Th = Therophytes, MMPh = Meso& Mega phanerophytes;**chorotype:** COSM = Cosmopolitan, PAN = Pantropical, PAL = Palaeotropical, NEO = Neotropical, ME = Mediterranean, ER-SR = Euro-Siberian, SA-SI = Saharo-Sindian, IR-TR = Irano-Turanian, S-Z = Sudano-Zambezian, AUST = Australian, Cult. & Nat. =Cultivated and Naturalized

Lemna minor* and *Potamogetonnodosus* represented 25%. The third group includes 17 taxa

Phragmitesaustralis has been recorded in all ecological sites (P=100%). Eleven species, namely

Alternantherasessilis, *Cyperusalopecuroides*, *Cyperus articulates*, *Cyperusdifformis*, *Echinochloastagnina*, etc. are very common in 3 sites (P = 75% each). *Cyperuslaevigatus* and*Leersiahexandra* have been recorded in two ecological sites (P = 50 % each) whereas, *Cyperus papyrus*, *Panicumrepens* and *Persicarialanigera* represented in one site only (P = 25% each).

The fourth group includes 44 species (canal bank species). Five species have been recorded in four ecological sites (P =100% each). They are *Alhagigraecorum*, *Cynodondactylon*, *Cynanchumacutum*, *Plucheadioscoridis* and *Symphyotrichumsquamatum*. Eighteen species recorded in three sites (P =75% each) and they including *Amaranthusviridis*, *Amaranthusgraecizans*, *Arundodonax*, *Bassiaindica*, *Bidenspilosa*, *Chenopodiummurale*, etc. Six species were observed in two ecological sites (P =50% each) and include *Amaranthuslividus*, *Echinochloacrusgalli* ,*Ethuliaconyzoides*, *Malvaparviflora*, Phyla nodiflora and *Suaedapruinosa*. Fifteen species have been recorded in one site only (P=25 % each) including *Arthrocnemummacrostachyum*, *Atriplexprostrata*, *Atriplexportulacoides*, *Atriplexsemibaccata*, *Chenopodiumficifolium*, etc.

The hydrophytes are absent in site 4, *Potamogetonperfoliatus* present only in site 1, while *Potamogetonnodosus* present only in site 2. *Cyperus papyrus* and *Pistia stratiotes* present only in site 3. The total number of recorded species constituted two major groups, 46 perennials and 24 annuals: Chenopodiaceae and Poaceae (14.28% each), Asteraceae (11.42%) and Cyperaceae (8.57%), Amaranthaceae and Polygonaceae (5.71% each), while the other families (24) is either represented by two or one species.

Chorological affinities

Chorological analysis revealed that the widely distributed species are belonging to Mediterranean element represented by 22 species or about 31.43% of the total recorded species. These taxa are pluriregional (9 species), biregional (12 species) or monoregional (one species). On the other hand, 39 species or about 55.71% of the total recorded species are either Cosmopolitan (18.57%), Palaeotropical, Pantropical (14.29% each) and Neotropical (8.57 %). The other floristic categories are poorly represented where each chorotype is represented by a few numbers of species (Table 2). In general, the percentages of the Cosmopolitan, Pantropical, Palaeotropical and Neotropical elements are obviously comparable in all surveyed ecological sites of the study area. The Mediterranean elements are highly represented in site 2 (14 taxa), followed by site 1 (12 taxa), site 3 (8 taxaeach) then site 4 (7 taxa).

Table 2. Number of species and percentage of various floristic categories of the ecological sites in the study area.

Floristic category	Total area		Ecological sites								Regional distribution
			Site 1		Site 2		Site 3		Site 4		
	No.	%	No.	%	No.	%	No.	%	No.	%	
COSM	13	18.57	10	22.22	13	25.00	11	23.40	2	12.50	World-wide
NEO	6	8.57	4	8.89	4	7.69	5	10.64	2	12.50	
PAN	10	14.29	5	11.11	9	17.31	9	19.15	-	-	

PAL	10	14.29	8	17.78	7	13.46	9	19.15	-	-	
ME+ER-SR+IR-TR	6	8.57	3	6.67	4	7.69	2	4.26	1	6.25	
ME+IR-TR+SA-SI	2	2.86	1	2.22	1	1.92	1	2.13	1	6.25	
ME+SA-SI+ER-SR	1	1.43	-	-	-	-	-	-	1	6.25	Pluriregional
ME+IR-TR	7	10.00	6	13.33	6	11.54	3	6.38	1	6.25	
ME+SA-SI	2	2.86	1	2.22	1	1.92	1	2.13	2	12.50	
ME+ER-SR	1	1.43	-	-	1	1.92	-	-	-	-	
ME+PAL	2	2.86	1	2.22	1	1.92	2	4.26	-	-	
S-Z+IR-TR	1	1.43	1	2.22	-	-	1	2.13	1	6.25	
S-Z+SA-SI	2	2.86	2	4.44	2	3.85	1	2.13	2	12.50	Biregional
ME	1	1.43	1	2.22	-	-	-	-	1	6.25	
S-Z	1	1.43	1	2.22	1	1.92	1	2.13	-	-	
AUST	1	1.43	-	-	-	-	-	-	1	6.25	
Cult. & Nat.	4	5.71	1	2.22	2	3.85	1	2.13	1	6.25	Monoregional
Total	70	100	45	100	52	100	47	100	16	100	

Ecological sites

١= El-Qanater El-Khayria – Benha, 2= Benha – El-Mansoura, 3 = El-Mansoura - Farskour, 4 = Farskour – Ras El-Bar

Classification of vegetation

The application of TWINSPAN classification on the importance values of 70 plant species recorded in 60 stands led to the recognition of four vegetation groups (A-D, Figure 2). The vegetational compositions of these groups are presented in Table (3). Group A (2 stands) codominated by *Phragmitesaustralis* (IV = 30.33) and *Bassiaindica* (IV = 24.26). Group B (8 stands) dominated by *Phragmitesaustralis* (IV = 23.40), these two groups were mainly occupied site 4. Group C (28 stands) codominated by *Saccharumspontaneum*(IV = 10.78) and*Phragmitesaustralis*(IV = 10.01) were inhabited the. Group D (22 stands) codominated by *Saccharumspontaneum*(IV = 8.78) and*Myriophyllumspicatum*(IV = 8.81).
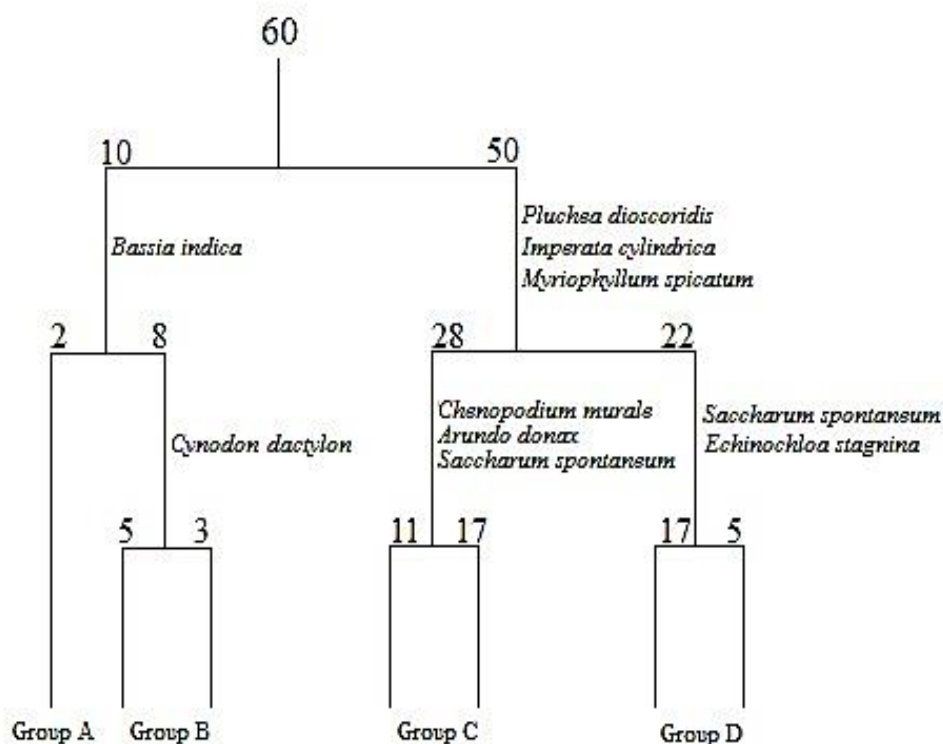
Figure 2. Two Way Indicator Species Analysis (TWINSPAN) dendrogram of the 60 sampled stands based on the importance values of the 70 species.

Stand ordination

Application of Principal Component Analysis (PCA) to the vegetation data (Figure 3) revealed the segregation of the 4 vegetation groups along PCA axis 1and 2. Group Acodominated by *Phragmitesaustralis*and *Bassiaindica* are separated at the lower part of the right side of the DCA diagram. However, group B dominated by *Phragmitesaustralis*is separated at the middle part of the lower side of the DCA diagram. Group C codominated by *Saccharumspontaneum*and*Phragmitesaustralis*aresegregated at the upper part of the left side of the DCA diagram. On the other hand, group D codominated by *Saccharumspontaneum*and*Myriophyllumspicatum*are segregated at the upper part of right side of the DCA diagram.

Vegetation-Environment Relationship

Significant differences in the examined hydrosoil variables within the separated vegetation groups derived from TWINSPAN classification were demonstrated in Table 3.The characteristics of most of the hydrosoil showed little variation between the different groups of stands. The soil texture in all groups is formed mainly of coarse fraction (sand) and partly of fine fractions (silt and clay). Bicarbonate, pH, EC, total nitrogen and phosphorus, sodium, potassium, calcium, sodium and potassium adsorption ratio showed clear significant differences between groups at $P < 0.001$, $P < 0.01$ and $P < 0.05$, respectively.
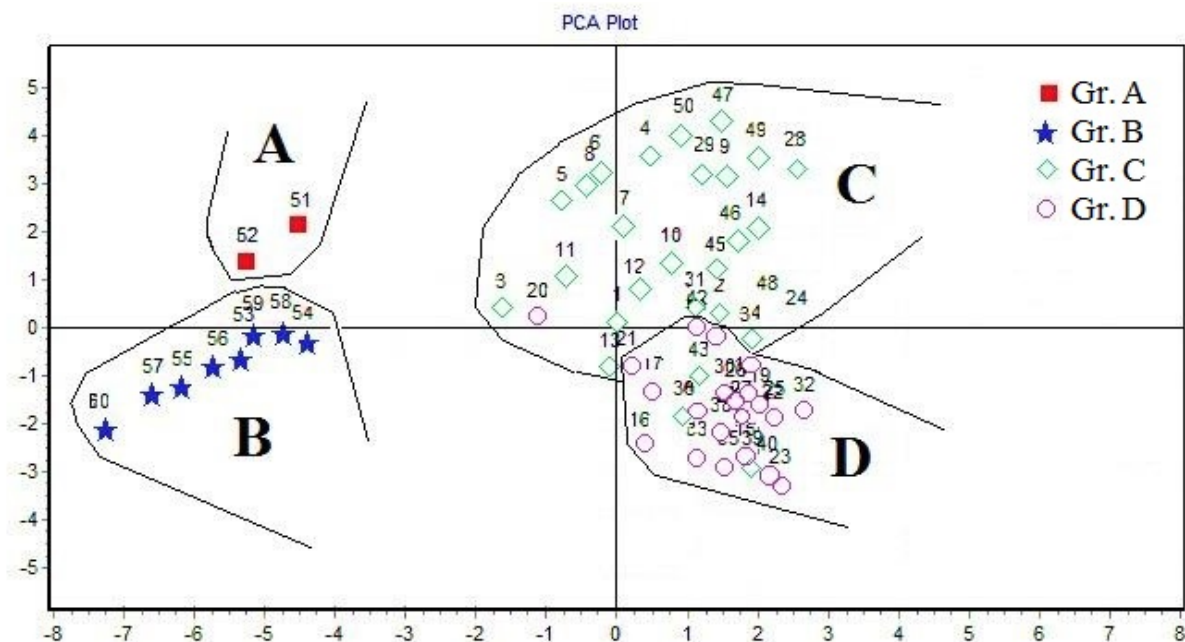
Figure 3.PCA diagram showing the distribution of the 60 stands of the different ecological sites in Damietta Branch within their vegetation groups.

Table 3. Means and standard errors of the different hydrosoil variables in the stands representing the different vegetation groups obtained by TWINSPAN classification in the study area.

Hydrosoil variable		Vegetation group				F-ratio	P -value
		A (n=2)	**B** (n=8)	**C** (n=28)	**D** (n=22)		
Sand	%	$87^b \pm 4$	$92.55^a \pm 1.39$	$88.06^{ab} \pm 0.95$	$87.19^b \pm 0.73$	2.78	0.06^{ns}
Silt		$11.75^a \pm 3.75$	$5.70^b \pm 1.21$	$10.38^{ab} \pm 0.89$	$10.98^a \pm 0.70$	3.72	0.02^*
Clay		$1.25^a \pm 0.25$	$1.75^a \pm 0.29$	$1.56^a \pm 0.12$	$1.83^a \pm 0.13$	1.02	0.40^{ns}
WHC		$55.65^a \pm 0.55$	$43.68^b \pm 3.52$	$53.33^a \pm 2.36$	$50.55^{ab} \pm 2.95$	2.27	0.11^{ns}
pH		$8.29^{ab} \pm 0.09$	$7.98^b \pm 0.14$	$8.35^{ab} \pm 0.09$	$8.34^a \pm 0.08$	3.48	0.03^*
EC(μmhos/cm)		$1171^{ab} \pm 94$	$1880.25^a \pm 782.72$	$380.18^b \pm 48.48$	$474.11^b \pm 56.95$	3.25	0.04^*
CaCO$_3$	%	$3.10^{ab} \pm 0.4$	$4.65^a \pm 0.89$	$4.01^{ab} \pm 0.45$	$3.99^b \pm 0.62$	2.11	0.12^{ns}
OC		$1.26^a \pm 0.6$	$1.03^a \pm 0.35$	$0.88^a \pm 0.10$	$0.68^a \pm 0.18$	0.62	0.61^{ns}
Cl$^-$		$0.17^a \pm 0.07$	$0.28^a \pm 0.18$	$0.06^a \pm 0.01$	$0.05^a \pm 0.01$	1.69	0.19^{ns}
SO$_4^{--}$		$0.19^{ab} \pm 0.05$	$0.39^a \pm 0.21$	$0.20^{ab} \pm 0.03$	$0.11^b \pm 0.05$	1.70	0.19^{ns}
CO$_3^{--}$		0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	-	-
HCO$_3^-$		$0.18^a \pm 0.09$	$0.11^b \pm 0.02$	$0.11^b \pm 0.01$	$0.09^c \pm 0.02$	5.70	0.004^{**}
TP	(mg/100g dry soil)	$1.56^b \pm 0.13$	$2.91^{ab} \pm 0.59$	$2.70^{ab} \pm 0.36$	$3.68^a \pm 0.45$	3.93	0.02^*
TN		$0.13^c \pm 0.05$	$0.26^{ab} \pm 0.04$	$0.24^b \pm 0.02$	$0.30^a \pm 0.03$	7.55	0.001^{***}
Na$^+$		$222.5^a \pm 96.5$	$111.02^b \pm 15.85$	$60.46^c \pm 7.66$	$41.72^c \pm 5.67$	17.88	0.000^{***}
K$^+$		$75.63^a \pm 45.08$	$32.29^b \pm 9.30$	$20.98^b \pm 2.99$	$10.29^b \pm 2.59$	8.21	0.0004^{***}
Ca^{++}		$28.30^b \pm 12.7$	$67.11^a \pm 21.30$	$28.80^b \pm 4.67$	$17.19^b \pm 3.05$	4.39	0.012^*
Mg^{++}		$53.50^a \pm 19.5$	$28.98^{ab} \pm 7.91$	$21.59^b \pm 3.20$	$22.70^b \pm 7.50$	2.49	0.012^{ns}

SAR	34.26^a±13.68	17.64^b±2.35	13.49^b±1.66	11.54^b±1.58	9.54	0.0002***
PAR	11.56^a±6.57	4.51^b±1.13	4.05^b±0.47	2.65^c±0.65	6.56	0.002**

WHC = Water holding-capacity; EC= Electrical conductivity; OC = Organic carbon; TP = Total phosphorus; TN = total nitrogen; SAR = Sodium adsorption ratio; PAR = Potassium adsorption ratio; *P ≤ 0.05, ** P ≤ 0.01, *** P ≤ 0.001, ns= non-significant

Some other soil variables showed no significant correlation such as soil texture (sand and clay), Water-holding capacity, calciumcarbonate, organic carbon, chloride, sulphate and magnesium. On the other hand, the water variables of the identified four vegetation groups are presented in Table 4. The characteristics of most of the water samples showed high variation between the different groups of stands. All water variables showed clear significant differences between groups at P < 0.001, P < 0.01 and P < 0.05, respectively, except BOD and calcium carbonate.

Table 4. Means and standard errors of the different water variables in the stands representing the different vegetation groups obtained by TWINSPAN classification in the study area.

Water variable		Vegetation group				F-ratio	P-value
		A (n=2)	**B** (n=8)	**C** (n=28)	**D** (n=22)		
Depth (cm)		191.25^b±4.25	222.5^a±15.43	175.45^b±5.09	176.93^b±5.86	5.14	0.006**
Temp. (°C)		22.50^b±0.4	22.64^b±0.40	30.13^a±0.31	30.35^a±0.43	86.34	0.000***
pH		7.60^b±0.0	7.65^b±0.04	8.03^a±0.06	7.99^a±0.09	17.87	0.000***
EC (μmhos/cm)		2690^b±250	3856.5^a±439.80	377.36^c±24.18	444.95^c±16.50	56.03	0.000***
O$_2$%		19.25^a±2.15	13.59^b±1.28	22.92^a±1.01	19.45^a±1.25	9.01	0.0002***
DO	mg/l	8.00^a±0.8	5.51^b±0.53	9.39^a±0.40	8.45^a±0.44	14.11	0.000***
BOD		17.05^a±1.95	10.54^b±2.14	12.64^a±1.92	22.28^{ab}±1.97	2.17	0.12^{ns}
COD		5.95^b±0.55	9.3^b±0.70	27.80^a±4.48	57.40^a±6.08	13.86	0.000***
Cl$^-$		5633.9^b±720.4	6688.9^a±434.71	1221.60^c±145.69	1210.37^c±180.04	104.91	0.000***
SO$^{--}_4$		2647.20^{ab}±36	4060.45^a±303.97	4414.83^a±628.58	2140.78^b±852.57	4.48	0.011*
CO$_3^{--}$		0±0.0	0±0.0	0±0.0	0±0.0	-	-
HCO$_3^-$		3336.70^b±329.40	4350.69^a±297.83	910.27^c±115.95	781.65^c±94.27	70.30	0.000***
CaCO$_3$		182.60^b±1	195.24^{ab}±9.32	188.06^a±7.19	186.49^{ab}±6.40	1.64	0.21^{ns}
TN		0.10^b±0.0	0.30^b±0.12	1.05^a±0.09	0.93^a±0.10	10.1	0.0001***
TP		0.60^c±0.0	0.83^{bc}±0.05	0.93^a±0.08	0.93^b±0.05	8.30	0.0004***
Na$^+$		4013.50^a±397.9	4480.45^a±368.01	311.59^b±59.26	545.42^{2b}±54.03	106.65	0.000***
K$^+$		462.15^a±37.05	524.11^a±43.01	33.05^b±5.65	58.64^b±5.59	113.78	0.000***
Ca^{++}		1036.00^a±114	1155.05^a±94.78	79.08^b±15.05	58.61^b±17.88	100.98	0.000***
Mg^{++}		370.20^b±12.6	460.70^a±50.32	33.95^c±5.64	61.79^c±6.42	62.70	0.000***

EC= Electrical conductivity; DO = Dissolved oxygen; BOD = Biological oxygen demand; COD = Chemical oxygen demand; TP = Total phosphorus; TN = total nitrogen; *P ≤ 0.05, ** P ≤ 0.01, *** P ≤ 0.001, ns= non-significant

The correlation between the vegetation and hydrosoil characteristics is shown on the ordination diagram produced by Canonical Correspondence Analysis (CCA) of the biplot of species-environment (Figure 4). It is clear that, the concentrations of sodium, percentages of SAR, water-holding capacity, total phosphorus, bicarbonates, and sulphates were the most effective hydrosoilvariables, they showed a high significant correlations with the first and second axes of CCA ordination diagram. The dominant and abundant species of group A (*Phragmitesaustralis, Bassiaindica*and*Cynanchumacutum*)are separated at the upper right side of CCA-biplot diagram. These species showed a close relationship with clay. *Phragmitesaustralis,* the dominant species, and the abundant species (*Suaedapruinosa, Halocnemumstrobilaceum*) in group B are separated at the right side of CCA of the biplot diagram and exhibited a distinct relationship with soil fractions (clay and silt), total phosphorus, nitrogen and pH.

In group C, however, the codominants (*Saccharumspontaneum, Phragmitesaustralis*) and abundant species (*Echinochloastagnina*and*Eichhorniacrassipes*) are separated at the upper side of CCA-biplot diagram. These species showed a close relationship with the concentration of sodium, percentages of SAR, water-holding capacity, bicarbonates, and sulphates.

On the other hand, the codominant species (*Saccharumspontaneum*and*Myriophyllumspicatum*)andmost important species(*Ceratophyllumdemersum*and*Eichhorniacrassipes*) in group D are separated at the left side of the diagram. These species showed a close relationship with sodium, SAR, water-holding capacity, bicarbonates, sulphates, magnesium and chlorides. The less important species are obviously segregated at the lower position of the right side of the CCA-biplot diagram.
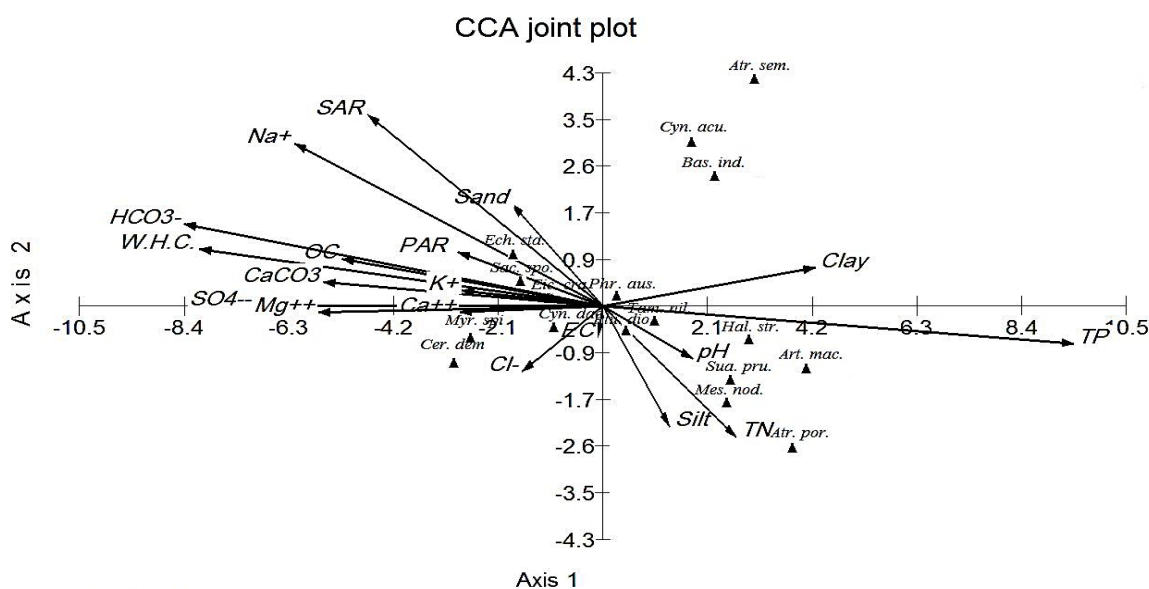
Figure 4.CCA-ordination diagram with hydrosoil variables represented by arrows. The indicator and preferential species are abbreviated to the first three letters of each of the genus and species.

The correlation between vegetation and water variables is shown in Figure (5). It is obvious that, chlorides, total phosphorus, sodium, SAR, potassium, PAR, magnesium, sulphates, electrical conductivity and calcium are the most important water variables which exhibited high significant correlations with the first and second axes of the CCA- biplot diagram.*Phragmitesaustralis*, the codominant species in all vegetation groups except group D, *Cynanchumacutum*(important species in group A), *Suaedapruinosa*, *Halocnemumstrobilaceum* (important species in group B) and *Echinochloastagnina* (abundant species in group C) are collectively separated at the right side of the diagram. These species showed a close relationship with chloride, sodium, magnesium, potassium, PAR, SAR, total phosphorus, chloride, COD and BOD. However, *Bassiaindica*, the codominant species in groups A,*Saccharumspontaneum*, the codominant species in groups C and D, *Cynodondactylon* , the indicator species in group A, *Myriophyllumspicatum,* the is codominant andmost important species(*Ceratophyllumdemersum*and*Eichhorniacrassipes*) in group Dare collectively segregated at the left- hand side of the diagram. These species showed a strong relationship with sulphate, pH value and temperature. On other hand, numerous less important species are obviously segregated at the right side of the diagram either at the upper or lower positions of the CCA-biplot diagram.
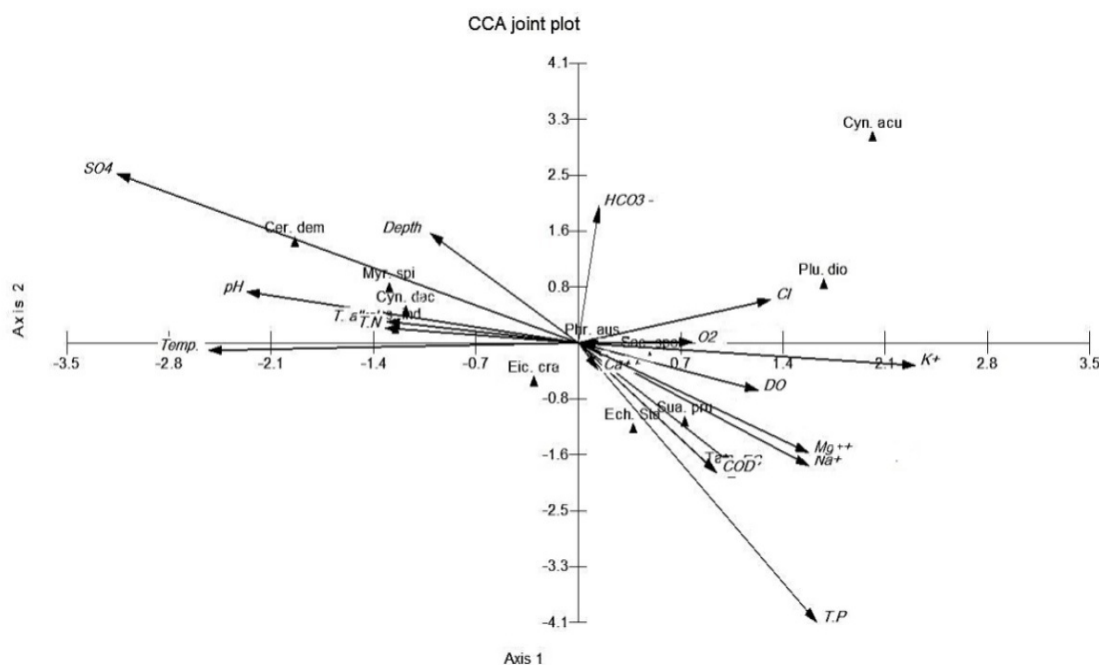
Figure 5.CCA-ordination diagram with water variables represented by arrows. The indicator and preferential species are abbreviated to the first three letters of each of the genus and species.

Discussion

The aquatic weeds decrease the velocity of water especially under heavy infestation. They cause water loss through evapotranspiration, silting and may cause a shortage of water. These weeds will

increase irrigation costs and hamper fisheries development. These weeds, particularly the emergent weeds, through their extensive food-storing rhizomes help in the erosion of the banks, their death and decay may leave small tunnels through which water seepage causes breaches or such tunnels are created by the rodents and crabs [25,26].

The Damietta branch of River Nile in Egypt is obviously populated by communities of macrophytes which spread very rapidly and fill up the whole water body in some ecological sites. Thus, water flow is noticeably hampered, so that either chemical, mechanical or biological maintenance is required.

Floristically, the total number of hydrophytes and terrestrial bank plants recorded in the present study is 70 species belonging to 54 genera grouped under 30 families. Out of these families, Chenopodiaceae and Poaceae(10 species each), Asteraceae (8 species) and Cyperaceae (6 species) are the main families being represented collectively about half (48.57%) of the total number of recorded species. These species are classified into major four groups: floating hydrophytes (6 species), submerged hydrophytes (3 species), emergent species (17) and terrestrial species (44). On the basis of duration, the recorded species (70) are grouped into two categories: perennials (46 species) and annuals (24 species).

According to the life-form spectra of the recorded species, the majority of plants are mainly cryptophytes (48.57 %) which include geophytes, helophytes and hydrophytes, and partly therophytes (34.29%). Chamaephytes (11.43%), hemicryptophytes (10.0%) and phanerophytes (5.72 %) constitute a relatively low representation of life-form spectra. In the present investigation, the floristic structure agrees more or less, with findings of Quezel[27] concerning the floristic structure of the Mediterranean Africa,El-Sheikh [28-29] and Mashaly et al. [30-31] on the canal-drain vegetation in the Nile Delta region, El-Amier [32] on phytosociological and autecological studies on the canal bank vegetation in Egypt and Shaltout et al. [33] studied the plant life in the Nile Delta.

Chorolgically, Egypt is the meeting point of the floristic elements belonging to at least four phytogeographical regions: the African Sudano-Zambesian, the Asiatic Irano-Turanian, the Afro-Asiatic Sahro-Sindian and the Euro-Afro-Asiatic Mediterranean [34]. The floristic analysis of the study area revealed that, about 31.43% of the total number of the recorded species are Mediterranean taxa. These taxa are either pluriregional (12.86%), biregional (17.14 %) or monoregional (1.43 %). It has been also found that, 39 species or about 55.71% of the total number of the recorded species are either Cosmopolitan (18.57%), Palaeotropical and Pantropical (14.29% each) or Neotropical (8.57 %). Similar investigations have been described by Shalaby[35], Khedr and El-Demerdash [36], Mashaly et al. [37, 31] andEl-Amier [32].

Ecologically, some plant species tend to have restricted range of distribution, others have wide range of ecological amplitudes and also others absent from some ecological sites. This restriction of

distribution is dependent on the need for a special habitat types such as the helophytic weeds in the wet habitat of the rice fields. The habitat types supporting the growth of the plant species in the present study are mainly hydric and / or canal bank habitats in the different sites of Damietta Branch, Egypt. It is very important to study the natural environmental conditions under which the plants grow naturally in order to know the best conditions under which each plant gives its maximum yield of growth containing the highest product of active materials of high potential economic values.

The weed vegetation in the present investigation is classified by TWINSPAN into four groups (A - D). The distinguished vegetation groups are obviously representing a special type of the surveyed ecological sites of Damietta Branch of River Nile in Egypt. Group A may represent the habitat type of site 4 (transitional zone) in which the identified co-dominant species are a mixture of *Phragmites australis* and *Bassiaindica* (indicator species). Group B may represent the habitats of ecological sites 4 (halophytes). This group is also dominated by *Phragmites australis*, but it is characterized by the important halophyte species *Suaeda pruinosa* and *Halocnemum strobilaceum.*

*Cynodon dactylon*is an indicator species. Group C may represent the habitat type of both site 1 and 3 which is codominated by *Saccharum spontaneum*and *Phragmites australis*, this group is characterized by the important true hydrophytic species *Eichhornia crassipes, Myriophyllum spicatum*, *Ceratophyllum demersum*, while the indicator species in this group are *Arundo donax* and *Chenopodium murale*. Group D may represent the habitats of both site 2 and 3. This group is codominated by *Saccharum spontaneum*(indicator species) and *Myriophyllum spicatum*. The important species in this group are typical hydrophytes including *Eichhornia crassipes* and *Ceratophyllum demersum*

It is worth to mention that similarities between the vegetation groups are obviously detected between groups A and B as well as also between groups C and D. Vegetationally, the identified groups in the present work can be classified into two main categories: the first category of the ecological site 4 (Farskour – Ras El-Bar) which includes groups A and B, and the second category of the ecological site 1, 2 and 3 (El-Qanater El-Khayria – Benha, Benha – El-Mansoura, and El-Mansoura - Farskour) which comprises groups C and D.

Freshwater aquatic plants are those that are physiologically adapted to survive in permanent or semi permanent freshwater ecosystems. The distribution and behavior of many aquatic plants are often correlated with water quality [38,39]. Ecosystems dominated by aquatic macrophytes are among the most productive in the world, largely as a result of ample light, water and nutrients, and the presence of plants that have developed morphological and biochemical adaptations enabling them to take advantage of these optimum conditions [40].

The ordination of the sampled stands in the present work obtained by Principal Component Analysis (PCA) indicates that the vegetation groups yielded by TWINSPAN classification are markedly

distinguishable and having a clear pattern of segregation on the ordination plane. It is of interest to note that, groups A and B are closely related to each other, also groups C and D are more or less related to each other. These specific relationships between the above mentioned pairs of vegetation groups may be due to the close similarities of their floristic composition and natural habitats.

In general, groups A and B may represent the associations of vegetation in the ecological sites 4, however groups C and D may represent the associations of vegetation in the ecological sites 1, 2 and 3.

The important soil gradients related to the distribution of vegetation as recognized by Shaltout and El-Sheikh [41, 42],Shaltout et al. [43], Al-Sodany [44]and Mashaly et al. [37, 31] are soil salinity (EC), moisture gradients, soil fertility (organic carbon, phosphorus and nitrogen contents), soil texture (sand, silt and clay), pH value and calcium carbonate content. In the present study, the application of Canonical Correspondence Analysis (CCA-biplot) indicates that, the most effective hydrosoil and water variables which significantly correlated with the abundance and distribution of vegetation groups are numerous such as soil texture (sand & silt), water-holding capacity, electrical conductivity, soluble anions (chloride &sulphate), total phosphorus, SAR, PAR and extractable cations (sodium, calcium & magnesium).

In the present study, CCA-biplot ordination diagrams indicate that, *Phragmites australis* as a codominant species in two vegetation groups (A & B) and dominant specie in group B, *Bassiaindica* as another codominant species in group A showed close relationships with soil fractions (clay and silt), water-holding capacity, sulphates, total phosphorus and nitrogen and pH. However, *Saccharum spontaneum*as the third codominant species in the vegetation groups (C & D) exhibited a distinct relationship with concentration of sodium, SAR, water-holding capacity, bicarbonates, sulphates, magnesium and chlorides. While *Myriophyllum spicatum*as an important codominant species in only one group D showed special type of relationship with sodium, SAR, water-holding capacity, bicarbonates, sulphates, magnesium and chlorides.

On the other hand, *Phragmites australis*, the codominant species in all vegetation groups except group D, *Cynanchum acutum* (important species in group A), *Suaeda pruinosa*, *Halocnemum strobilaceum* (important species in group B) and *Echinochloa stagnina* (abundant species in group C), these species showed a close relationship with chloride, sodium, magnesium, potassium, PAR, SAR, total phosphorus, chloride, COD and BOD. However, *Bassiaindica*, the codominant species in groups A, *Saccharum spontaneum*, the codominant species in groups C and D, *Cynodon dactylon* , the indicator species in group A, *Myriophyllum spicatum*, the codominant andmost important species(*Ceratophyllum demersum* and *Eichhornia crassipes*) in group D showed a strong relationship with sulphate, pH value and temperature. These results are in line with those of Serag et al. [46], Mashaly et al. [31] and El-Amier [32].

Dissolved oxygen concentration is one of the most important and limiting factor since it is essential for respiration of an aquatic member of the fauna and flora [47, 48]. In the present study, dissolved oxygen concentration was high in group A. Obviously, the concentration of eutrophication key elements i.e. P and N were the highest at group B and D. The process of eutrophication brings about changes in the aquatic flora [49, 50] The greatest changes frequently results from human activities, because these may alter water chemistry, clarity and temperature, factors linked with species changes [51, 52].

The marked regional variations of many investigated parameters may be attributed to the effect of pollution point sources. In this connection, Hegewald and Runkel[53] reported that any water body influenced by agricultural discharges is certainly unstable in chemical composition. Therefore, it was not a surprise to find inferior water quality at the Delta region of the River Nile. On the other hand, groups C and D attained the lowest values of some measured parameters; these groups represent sites 1, 2 and 3.

The aquatic plants recorded in our study have certain feature in common, e.g. vegetative reproduction and relatively rapid growth; this is in accordance with Murphy et al. [54] andYacoub [55]. Others may tolerate physical disturbance by being strong and flexible according to Spink [56].

Conclusion

The above mentioned results reveal that, site 2 is floristically the richest among all the ecological sites, followed by site 3, then site 1 and finally site 4. Cryptophytes (geophytes, helophytes and hydrophytes) were the most abundant life form and constituted 48.57% of the total flora, followed by therophytes (34.29%), chamaephytes (11.43%), hemicryptophytes (10.0%) and phanerophytes (5.72%). It is worth to mention that, the life-form specAtrum in all ecological sites of the study area is mainly represented by cryptophytes and partly by therophytes, chamaephytes, hemicryptophytes and phanerophytes.

It can be concluded that, the successive changes of the macrophytic plant vegetation in the Damietta Branch, River Nile in Egypt are frequently results from human activities, because these may alter water chemistry, clarity and temperature, factors linked with species changes [51,57]. The high concentrations recorded of the studied elements are mainly attributed to the agricultural, urban discharge and industrial effluents [58]. The results of this study are mostly in accordance with earlier findings obtained from other aquatic environments in Egypt [59, 60, 32].

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